IMPROVEMENT OF THE PRODUCTION QUALITY

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IMPROVEMENT OF THE PHYSICOCHEMICAL PROPERTIES OF DIELECTRIC GLASS

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The paper contains the results of research on methods of improving the physicochemical properties of dielectric glass by applying protective strengthening coatings and magnetic treatment of a glass drop, as well as the parameters of coating application and fixation.

The physicochemical properties of glass depend on the state of its surface. It is known that the theoretical strength of glass is high and the practical strength is low, which is determined by the weakening effect of the surface microdefects and the influence of surface-active environments.

Considering that dielectric glass is used in production of the line high-voltage insulators that operate on the power lines located in different climatic zones and the areas of industrial pollution of the atmosphere, the problem of maintaining and improving the physicochemical parameters of such glass appears very important.

It is possible to improve the physicochemical properties of glass by different methods. The methods of application of protective strengthening coating, magnetic treatment of glass, and solid-phase ion-exchange strengthening appear very interesting since they can be combined effectively with the exist industrial technology for production of annealed and hardened insulators and are the most accessible means for imparting new physicomechanical and chemical properties to the glass.

It is known that the application of these methods makes it possible to increase the physicochemical parameters of packaging and window glass containing one alkali oxide (Na_2O) [1, 2]. The dielectric insulating glass contains two alkali oxides ($Na_2O + K_2O$), which can considerably affect the nature and parameters of strengthening especially in solid-phase ion-exchange strengthening during which sodium ions in the surface layer of the glass are replaced by potassium ions.

In order to develop an effective composition and strengthening parameters for insulating glass, as applied to the existing technology for production of line insulators, we investigated the methods for improvement of the properties of this glass based on the application of protective strengthening coating and on magnetic treatment of glass.

Application of protective strengthening coating. The experiments were performed on 120 × 35 × 15 mm samples and ShS10-D insulators molded from dielectric glass of composition 7.

Aqueous emulsions of organosilicon liquids with oleic acid and chromolan as emulsifiers were selected for protective-strengthening coating and were deposited on the surface in the form of aerosol. The temperature and time procedures for application and fixation of the coating were within the limits of the technological parameters of the insulator manufacture.

The prepared emulsions were applied to the heated samples and insulators with an injector, and the coating was fixed in an electric muffle furnace according to the insulator annealing procedure.

The best results were obtained for application of aqueous organosilicon emulsions containing (here and elsewhere, wt.% is indicated): 80% liquid, 119 – 215.5 oleic acid, 15 water (composition 13), and also 20 emulsion KE-10, 50 polymethylsiloxane liquid PMS-100, 30 water (composition 15). The parameters of application and fixation of the organosilicon emulsion are effectively combined with the technological parameters of insulator manufacture. Thus, in applying protective-strengthening coating of compositions 13 and 15, the sample temperature was equal to 550°C, the heating period was 7 – 8 sec, and the maximum temperature of fixation was 580°C.

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On the basis of the parameters developed, a set of samples for comprehensive testing was made. The following characteristics were determined in the samples: surface contact angle of wetting; surface resistance to the effect of 0.5 NHCl and NaOH; qualitative change of the surface on impact of marine entrainment of the composition (%): 3.0 NaCl, 3.8 MgCl, 0.9 $CaSO_4$, O.1 $CaCO_3$, and saline sediments of the composition (%): 42.0 quartz sand, 13.4 kaolin, 14.0 chalk, 3.5 salt, 3.9 gypsum, 1.5 blue vitriol; washability of contaminants (kaolin emulsion of density 1.8 – 2.0 g/cm^3), as well as heat resistance and bending strength. Table 1 shows the average values of the test results for the glass samples.

The analysis of the data obtained makes it possible to conclude that the developed parameters for application and fixation of the coating allow improving the hydrophoby of the glass surface. The contact angle of wetting increased by a factor of 6, the surface resistance to the effect of 0.5 NHCl was doubled, the resistance to the effect of alkali, marine entrainment and saline sediments was enhanced, the surface contamination decreased, and the washability was doubled. Moreover, the protective strengthening coating increases the heat stability by 34% and the mechanical strength by 57%.

The improvement of the above properties of the molded samples results from the interaction of the glass surface with the organosilicon compound having chemical affinity with the glass. This interaction produces chemical modification of the glass surface, including modification of microdefects. It is confirmed by the change in the glass strengthening level depending on the defects on its surface [2].

TABLE 1

Parameter	Sample	
	without coating	with protective strengthening coating
Contact angle of wetting, deg	11.6	71.0
Surface resistance to effect of 0.5 NHCl after 7 days of exposure, mass losses attributed to the sample surface area, 10^{-4} g/mm^2	39.0	16.0
Surface resistance to effect of 0.5 NNaOH after 7 days of exposure, surface state	Dull	Without change
Surface resistance to marine entrainment effect after 7 days of exposure, surface state	Dullness weakly expressed	The same
Surface resistance to saline sediment effect after 7 days of exposure, surface state	Dull	"
Surface pollutability and washability, quantity of sedimented and remaining contamination attributed to the sample surface area unit, 10^{-4} g/mm^2:		
sedimented contamination	2766	2077
remaining contamination	186	84
Heat resistance, °C	35	55
Bending strength, MPa	13.06	22.35

Moreover, the organosilicon coating implements the physicochemical protection of the surface from the action of the surface-active environment and serves as a kind of protector reducing the probability of its mechanical damage on contact with abrasive particles and solid bodies.

The results obtained indicate that the application of a protective coating on the insulators can improve significantly their properties and increase their service reliability.

With the aim of developing the optimum parameters for application of a protective strengthening coating on the insulators and determining their properties (taking into account the scale factor and the configuration of the product), based on the parameters obtained, a series of insulators ShS10-D were manufactured and comparative tests were performed on them. The consumption of aqueous emulsions of organosilicon liquid per insulator amounted to 10 – 15 ml, the temperature of the insulator surface was 550°C, the maximum temperature of the coating fixation was 580°C, the fixation process time depended on the insulator annealing procedure (the total duration was 3.5 h).

The influence of the protective strengthening coating on the parameters of the insulators was determined by testing them for thermal stability, mechanical strength, contact angle of wetting of the insulator surface, discharge and withstand voltage at frequency 50 Hz in the dry state and in rain, dielectric loss tangents and elucidation of its distribution probability.

The thermal stability, mechanical strength, discharge and withstand voltage in the dry state and in rain were determined by GOST 1232–82. The dielectric loss tangent was determined in the following way. The insulator head was placed in a water-filled cap, a rod was inserted into the head and was filled with water up to the beginning of the thread. An E7-8 device was connected to the rod and to the cap and recorded the values of the dielectric loss tangent. The test was conducted on 25 insulators. The average test values for ShS10-D insulators are presented in Table 2.

The data obtained indicate that the heat resistance of the insulators with the coating increased by 18%, the mechanical strength grew by 16%, the contact angle of surface wetting

TABLE 2

Parameter	Insulator ShS10-D	
	with coating	without coating
Heat resistance, °C	51	43
Mechanical fracture force, kN	15.38	13.26
Contact angle of wetting, deg	75.0	11.5
Industrial frequency voltage in dry state, kV:		
discharge	67.40	65.17
withstand	60.66	58.80
Industrial frequency voltage in rain, kV:		
discharge	59.53	47.96
withstand	52.00	41.96
Dielectric loss tangents	0.019	0.089

grew 6-fold, the discharge and withstand voltage in the dry state grew insignificantly (by 3%), the discharge and withstand voltage in rain increased by 25%, and the dielectric loss tangents decreased nearly 4.6-fold. Moreover, more stable results were obtained (see Figure) which will provide for increased resistance of the insulators to chemical actions, thermomechanical loads, and a high voltage effect.

The test of the efficiency of the protective strengthening coating of the insulators confirmed the improvement of their physicochemical properties, stability of the strengthening effect and reliable technological reproducibility in industrial production.

Use of the protective strengthening coating will make it possible to increase significantly the service reliability of the insulators.

Based on the parameters developed, an experimental unit for applying the coating to ShS10-D insulators in the course of their manufacture was designed and installed at the production line of the Lvov Insulator Plant.

A series of ShS10-D insulators with the protective coating is now in trial operation.

The method of magnetic treatment of glass. In recent years a new trend in improvement of the quality of glass products and physicochemical properties of glass has evolved based on the effect of external magnetic fields on melts. Such an effect is used in hardening of metals, concrete, reinforced concrete products, and glass (Author's certificate Bulgaria 30385) [3, 4].

In order to determine the effect of magnetic treatment on the properties of a drop of insulating glass of composition 7 the following experiment was performed. Glass samples of composition 7, and size of 120 × 35 × 15 mm were molded in the experimental shop of the Science and Research Institute of High Voltage both with magnetic treatment of the glass drop and without magnetic treatment. The parameters of treating the glass drop were based on an analysis of the literature data: magnetic field strength of 0.1 – 0.15 T, treatment time of 0.2 sec. In manufacture of the samples, the dependence of the strengthening effect on the glass temperature and the rate of its cooling after magnetic treatment were also taken into account.

The samples were tested for static bending strength and heat resistance. The average values of the test results for the glass samples are given in Table 3.

As can be seen, the heat resistance of the glass increased by 2.5 % and its mechanical strength grew by 32%. Moreover, in the course of molding, a decrease in the viscosity of the glass treated with the external magnetic field was observed, which improved molding of the samples and the quality of their surface.

The deciding factor in improvement of the parameters of glass treated with an external magnetic field, in our opinion, is polarizing orientation of molecules and molecular aggregates under the effect of the external and self-induced force fields during formation of the glass structure.

The experiments carried out give reason to accept the magnetic treatment method as a possible technique to be used for the purpose of improving glass molding technology and increasing glass strength. With a low level of material expenditures and without disturbing the existing technological process, the use of this method will allow significantly improving the mechanical properties of glass insulators and other glass products.

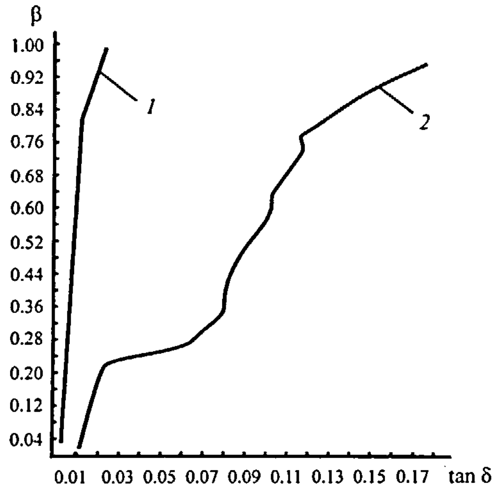

Fig. 1. Probability of distribution β of the dielectric loss tangents tan δ for Sh10-D insulators with coating (*1*) and without coating (*2*).

TABLE 3

Parameter	Sample	
	glass without treatment	glass after magnetic treatment
Heat resistance, °C	161	165
Static bending strength, MPa	37.01	49.18

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